Electric Current

Net Flow of charge:

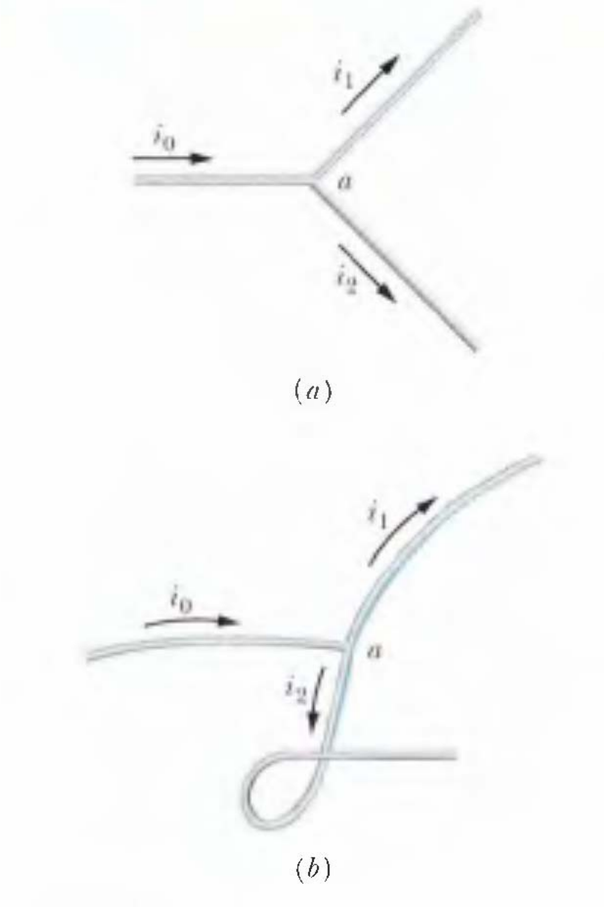
- not random movement
- not equal amount of positive and negative

$$i = \frac{dq}{dt} \qquad \text{(definition of current).}$$

$$q = \int dq = \int_0^t i \, dt,$$

Note:
Current may
vary with
time

$$1 \text{ ampere} = 1 \text{ A} = 1 \text{ coulomb per second} = 1 \text{ C/s}.$$



If current splits: $i_0=i_1+i_2$

Note: Current is a scalar!

Draw current arrows in direction of positive "charge carriers".

Current Density

Current per unit area, such that: $$i = \int \vec{J} \cdot d\vec{A}.$$

If current is uniform and parallel to dA then:

$$i = \int J\,dA = J \int dA = JA,$$

$$J = \frac{i}{A},$$

Drift Speed

V_d is drift speed, not speed of flow

Can relate V_d to J

Total charge in length L (n=carriers per unit volume) = $q = (nAL)e$

Time to move distance L: $t = \frac{L}{v_d}.$

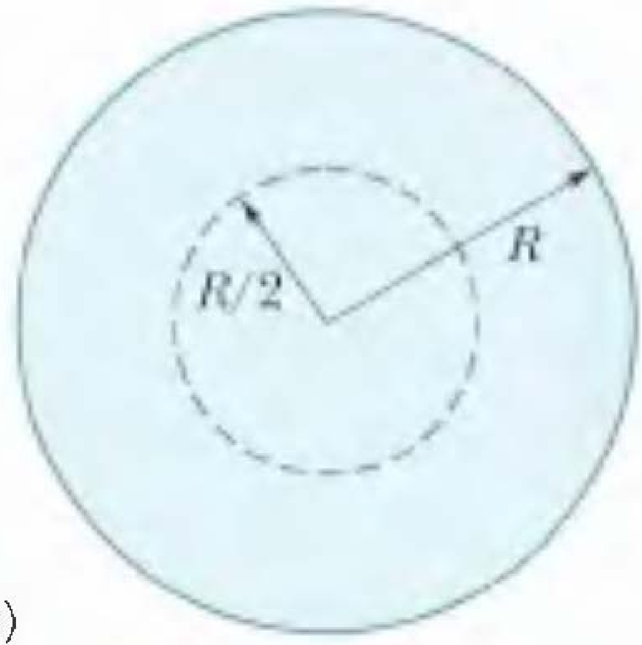
$$i = \frac{q}{t} = \frac{nALe}{L/v_d} = nAev_d.$$

$$i = \frac{q}{t} = \frac{nALe}{L/v_d} = nAev_d.$$

$$v_d = \frac{i}{nAe} = \frac{J}{ne}$$

$$\vec{J} = (ne)\vec{v}_d.$$

(a) The current density in a cylindrical wire of radius $R = 2.0$ mm is uniform across a cross section of the wire and is $J = 2.0 \times 10^5\ \text{A/m}^2$. What is the current through the outer portion of the wire between radial distances $R/2$ and R (Fig. 26-6*a*)?



(*a*)

Sample Problem 26-3

What is the drift speed of the conduction electrons in a copper wire with radius $r = 900\ \mu\text{m}$ when it has a uniform current $i = 17\ \text{mA}$? Assume that each copper atom contributes one conduction electron to the current and that the current density is uniform across the wire's cross section.

Resistance and Resistivity

Difference in current (i) due to voltage (V) is termed resistance (R)

$$R = \frac{V}{i} \qquad \text{(definition of } R\text{).}$$

$$1 \text{ ohm} = 1\ \Omega = 1 \text{ volt per ampere}$$

Can define resistivity in terms of electric field and current density

$$\rho = \frac{E}{J} \qquad \text{(definition of } \rho\text{)}.$$

$$\frac{\text{unit }(E)}{\text{unit }(J)} = \frac{\text{V/m}}{\text{A/m}^2} = \frac{\text{V}}{\text{A}}\,\text{m} = \Omega \cdot \text{m}.$$

Conductivity:

$$\sigma = \frac{1}{\rho} \qquad \text{(definition of } \sigma\text{)}.$$

Unit: mho/meter

Calculating Resistance from Resistivity

Resistance is a property of an object. Resistivity is a property of a material.

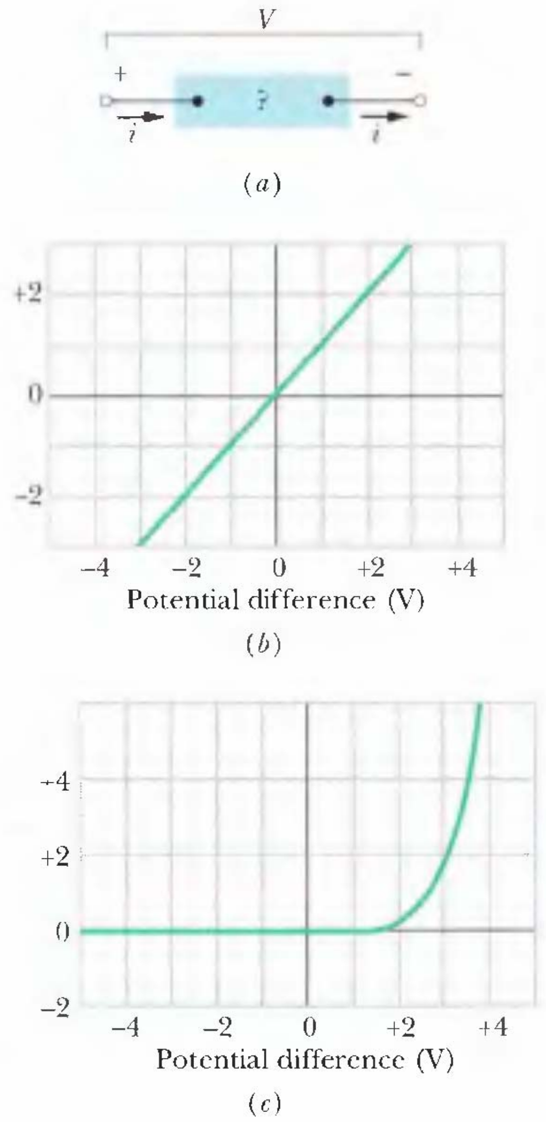
$$E = V/L \quad \text{and} \quad J = i/A.$$

$$\rho = \frac{E}{J} = \frac{V/L}{i/A}.$$

$$R = \frac{V}{i}$$

$$R = \rho\frac{L}{A}.$$

Ohm's Law



V
+
−
?
i
i
(a)
+2
0
−2
−4
−2
0
+2
+4
Potential difference (V)
(b)
+4
+2
0
−2
−4
−2
0
+2
+4
Potential difference (V)
(c)

☛ **Ohm's law** is an assertion that the current through a device is *always* directly proportional to the potential difference applied to the device.

☛ A conducting device obeys Ohm's law when the resistance of the device is independent of the magnitude and polarity of the applied potential difference.

☛ A conducting material obeys Ohm's law when the resistivity of the material is independent of the magnitude and direction of the applied electric field.

27.6 A current of 7.5 A is maintained in a wire for 45 s. In this time **(*a*)** how much charge and **(*b*)** how many electrons flow through the wire?

The number of electrons N is given by

A copper bus bar carrying 1200 A has a potential drop of 1.2 mV along 24 cm of its length. What is the resistance per m of the bar?

5 A current of 3.0 A flows down a straight metal rod that has a 0.20-cm diameter. The rod is 1.5 m long, the potential difference between its ends is 40 V. Find (*a*) current density and (*b*) field in the rod, and (c) resistivity of the material of the rod.

Power: Rate of electrical energy transfer

$$dU = dq\, V = i\, dt\, V.$$

Power is dU/dt

$$P = iV$$

$$1\ \text{V} \cdot \text{A} = \left(1\ \frac{\text{J}}{\text{C}}\right)\left(1\ \frac{\text{C}}{\text{s}}\right) = 1\ \frac{\text{J}}{\text{s}} = 1\ \text{W}.$$

For resistor:

$$P = i^2 R$$

or

$$P = \frac{V^2}{R}$$

You are given a length of uniform heating wire made of a nickel–chromium–iron alloy called Nichrome; it has a resistance R of 72 Ω. At what rate is energy dissipated in each of the following situations? (1) A potential difference of 120 V is applied across the full length of the wire. (2) The wire is cut in half, and a potential difference of 120 V is applied across the length of each half.